Diagnostic criteria for diabetes mellitus and other categories of glucose intolerance: 1997 criteria by the Expert Committee on the Diagnosis and Classification of Diabetes Mellitus (ADA), 1998 WHO Consultation criteria, and 1985 WHO criteria

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Abstract

To compare 1997 ADA diagnostic criteria for diabetes mellitus and other categories of glucose intolerance/1998 WHO Consultation criteria versus 1985 WHO criteria, we analyzed data from a 75-g oral glucose tolerance test (OGTT) performed on 1051 high-risk subjects without medical history of diabetes at Diabetes Screening Clinic, Ramathibodi Hospital, Thailand. There were 372 males and 679 females, aged (mean ± S.D.) = 50.3 ± 12.55 years, BMI = 25.62 ± 4.39 kg/m². If fasting plasma glucose (FPG) was used as recently recommended then 54.1, 20.4, and 25.5% of cases were classified as normal, impaired fasting glucose (IFG), and diabetic, respectively. In diagnosing diabetes using a full OGTT based on the 1985 WHO criteria as the reference test, FPG ≥ 7 mmol/l had a sensitivity of 57.7%, specificity of 97.4%, positive predictive value of 94.0%, and negative predictive value of 76.4%; 53.7% of subjects with IFG had 2-h plasma glucose ≥ 11.1 mmol/l. The 1997 ADA/1998 WHO Consultation criteria and 1985 WHO criteria for a full OGTT yield similar overall results. FPG (≥ 7 mmol/l) was not sensitive for diagnosing diabetes. Moreover, about half of the subjects with IFG were actually diabetic. Therefore, OGTT remains a valuable test in diagnosing diabetes and classifying various categories of glucose intolerance. © 1999 Elsevier Science Ireland Ltd. All rights reserved.

Keywords: Diabetes mellitus; Glucose intolerance; Blood glucose; Glucose tolerance test; Impaired fasting glucose; Impaired glucose tolerance

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1. Introduction

Diabetes mellitus is a group of metabolic diseases characterized by hyperglycemia resulting from defects in insulin secretion, insulin action or both [1]. Diagnostic criteria and classification of diabetes mellitus and other categories of glucose intolerance currently used in most countries are those recommended by the World Health Organization (WHO) Expert Committee in 1980 [2] and later slightly modified by the WHO Diabetes Study Group in 1985 [3], which were based on those proposed by the National Diabetes Data Group (NDDG) in 1979 [4]. As more information has been gathered over nearly the past two decades, new criteria for diagnosis and classification of diabetes mellitus and related disorders were proposed in 1997 by the Expert Committee on the Diagnosis and Classification of Diabetes Mellitus sponsored by the American Diabetes Association (ADA). In essence, fasting plasma glucose (FPG) ≥ 7 mmol/l (126 mg/dl) is introduced as the preferred criterion for diagnosis of diabetes mellitus. Previously, FPG ≥ 7.8 mmol/l (140 mg/dl) was recommended as one criterion for diagnosing diabetes mellitus [2–4]. A new stage of glucose intolerance called impaired fasting glucose (IFG) is introduced which includes subjects with fasting plasma glucose ≥ 6.1 mmol/l (110 mg/dl) and < 7 mmol/l (126 mg/dl). Normal subjects have FPG less than 6.1 mmol/l (110 mg/dl). In case an oral glucose tolerance test is necessary, a 75-g oral glucose load is also recommended and the cutpoint for 2-h plasma glucose concentration (2-h PG) remains the same as used previously [2–4], i.e. 11.1 mmol/l (200 mg/dl). In July 1998, a provisional WHO Consultation report was published [5] in which similar cutpoints for FPG and 2-h plasma glucose values were proposed. A new stage of glucose intolerance called impaired fasting glycemia (IFG) is introduced to encompass fasting plasma glucose values ≥ 6.1 mmol/l (110 mg/dl) and < 7 mmol/l (126 mg/dl).

Certain impacts on public health care systems are expected to result from the new criteria, especially as more subjects will be classified as having diabetes. The purpose of this study was to compare the new 1997 diagnostic criteria for diabetes as proposed by the Expert Committee on the Diagnosis and Classification of Diabetes Mellitus (ADA), the 1998 WHO Consultation criteria, and the 1985 WHO criteria, for the diagnosis and categorization of diabetes mellitus and other categories of glucose intolerance.

2. Materials and methods

A 75-g oral glucose tolerance test was performed on 1051 subjects who had no medical history of diabetes mellitus, at the Diabetes Screening Clinic, Ramathibodi Hospital, Bangkok, Thailand, between July 1982 and January 1993. They were referred to the clinic because of having known risk factors for glucose intolerance, i.e. a family history of diabetes, a history of gestational diabetes, obesity, and previously borderline blood glucose values.

Every subject was an ambulatory outpatient and had a non-restricted diet for at least 3 days. The subjects took no drugs known to affect glucose tolerance. The oral glucose tolerance test was carried out as outlined by the WHO Diabetes Study Group [2]. Plasma glucose concentration was measured by a glucose oxidase method using a Beckman glucose analyzer [6]. The intraassay and interassay coefficients of variation (CVs) for plasma glucose were 0.67 and 3.19%, respectively, at 5.6 mmol/l (100 mg/dl), and 0.73 and 2.44%, respectively, at 15.7 mmol/l (283 mg/dl).

Categorization of the 1051 study subjects based on FPG and a full OGTT were performed according to the 1997 ADA/1998 WHO Consultation criteria and 1985 WHO criteria [1,3,5].

2.1. Statistical methods

Data are presented as means ± S.D. Differences between means were assessed by unpaired Student’s t-test. Statistical significance was set at P < 0.05. Sensitivity, specificity, and positive and negative predictive values were calculated using standard formulas [7].
3. Results

The clinical characteristics and glycemic indexes of the 1051 subjects are summarized in Table 1. There were 372 men (35.4%) and 679 women (64.6%), aged 15–85 years (mean ± S.D. = 50.03 ± 12.55 years). Body mass indices ranged from 14.04 to 45.39 kg/m² (mean ± S.D. = 25.62 ± 4.39 kg/m²).

The result of an oral glucose tolerance test (OGTT) performed on 1051 subjects is summarized in Table 2. If fasting plasma glucose was used in the diagnosis and classification of diabetes mellitus and other categories of glucose intolerance, as recently recommended by the ADA Expert Committee (1997) [1], 268 cases (25.5%) were diabetic (Table 3), in contrast to 453 cases (43.1%) detected by a full OGTT based on the 1997 ADA or 1998 WHO Consultation criteria. In regard to diagnosing diabetes mellitus using a full OGTT (ADA 1997: WHO Consultation 1998) as a gold standard, FPG (≥ 7 mmol/l or 126 mg/dl) had a sensitivity of 59.2%, a specificity of 100%, a positive predictive value of 100%, and a negative predictive value of 76.4%. If the cutpoint of FPG was set at 7.8 mmol/l (140 mg/dl), as earlier recommended by the NDDG [4] and the WHO Diabetes Study Group [3], the sensitivity was only 36.2%, the specificity was 100%, the positive predictive value was 100%, and the negative predictive value was 67.4%. Among 214 cases (20.4%) classified as IFG (Table 3), 115 cases (53.7%) were diabetic and 70 cases (32.7%) had impaired glucose tolerance (IGT). As shown in Table 2, 251 (93.7%) of 268 cases classified as diabetic according to FPG ≥ 7 mmol/l (126 mg/dl) had a 2-h PG ≥ 11.1 mmol/l (200 mg/dl), and four cases (1.5%) had a 2-h PG < 7.8 mmol/l (140 mg/dl). Among 569 subjects with normal FPG, 70 cases (12.3%) were diabetic, 192 cases (33.7%) had IGT, and only 307 cases (54.0%) had normal OGTT based on the 1997 ADA or 1998 WHO Consultation criteria (Table 3). There were no differences in age or body mass index between those with IFG who were diabetic and those who were nondiabetic.

4. Discussion

The revised criteria for diagnosis of diabetes mellitus and other categories of glucose intolerance proposed by the Expert Committee on Diagnosis and Classification of Diabetes Mellitus (ADA) in 1997 are still based on the degree of hyperglycemia [1]. Because blood glucose is a continuum, the choice of a distinct cutpoint will always be somewhat arbitrary [8] even though there is an approximate threshold separating those subjects who are at substantially increased risk for certain complications from diabetes [1]. If a full OGTT based on the 1985 WHO criteria was used as the reference test, FPG ≥ 7 mmol/l (126 mg/dl) as a criterion for diagnosis of diabetes mellitus had a sensitivity of 57.7%, a specificity of 97.4%, a positive predictive value of 94.0%, and a negative predictive value of 76.4%. Comparable results were obtained when a full OGTT based on the 1997 ADA or 1998 WHO Consultation criteria was used as the reference test, the FPG test had a sensitivity of 59.2%, a specificity of 100%, a
positive predictive value of 100%, and a negative predictive value of 76.4%. This finding is not unexpected because comparison of the 1997 ADA/1998 WHO Consultation criteria based on a full OGTT versus the 1985 WHO criteria (Table 3) revealed similar overall results. The 100% specificity and positive predictive value of the FPG test are by definition 100%, since the same cut-point (7 mmol/l or 126 mg/dl) is part of the OGTT according to the 1997 ADA or the 1998 WHO Consultation criteria.

When a full OGTT based on the 1997 ADA or 1998 WHO Consultation criteria was applied as the reference test and using data from the third National Health and Nutrition Examination Survey (NHANES III) for individuals 40–74 years old without a medical history of diabetes [9], the FPG test (≥ 7 mmol/l or 126 mg/dl) had a sensitivity of 58.6%, a specificity of 100%, a positive predictive value of 100%, and a negative predictive value of 96.5%. These findings are generally comparable to our figures. It is quite interesting because our subjects were hospital-based and at risk for diabetes while the data from the NHANES III were derived from representative subjects of the USA population. The estimated sensitivities of the FPG test derived from a population-based study in three ethnic groups in the UK [10] were 62.1, 72.7, and 71.4% for Europeans, Chinese, and South Asians, respectively. The reference test in this report was the 1985 WHO 2-h PG criterion. If this reference test was applied to our study, the FPG test had a sensitivity of 57.6%. The numbers of diabetic subjects in the UK study were relatively small because it was a population-based study. Interestingly, in the populations studied the 1997 ADA criteria (using FPG only) would increase the prevalence of diabetes in addition to classifying some individuals diabetic by the 2-h PG ≥ 11.1 mmol/l (200 mg/dl) as nondiabetic. The effect of applying the new 1997 ADA criteria or the 1998 WHO Consultation criteria using FPG on the prevalence of diabetes in population-based studies may vary between studies [1,10], and the reasons for the difference are not clear. Our study was hospital-based and the prevalence of diabetes was lower when the 1997 ADA/1998 WHO Consultation criteria using FPG was applied, in comparison to the 1985 WHO criteria or the 1997 ADA/1998 WHO Consultation criteria using a full OGTT. Our finding is similar to the results from the NHANES III [1] and the another population-based study in individuals ≥ 20 years old from Taiwan [11]. Weiner and Roberts [12] studied 401 subjects referred for an OGTT and found that the FPG test classified 166 subjects as diabetic (prevalence of diabetes = 41.4%), and had a sensitivity

### Table 2

Categorization of glycemic status using FPG and 2-h PG in the 1051 subjects based on 1985 WHO, 1997 ADA, and 1998 WHO Consultation diagnostic criteria

<table>
<thead>
<tr>
<th>FPG (mmol/l)</th>
<th>2-h PG (mmol/l)</th>
<th>Number of subjects (%)</th>
<th>1985 WHO criteria</th>
<th>1997 ADA/1998 WHO Consultation criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;7</td>
<td>&lt;7.8</td>
<td>336 (32.0)</td>
<td>Normal or unclassifiable&lt;sup&gt;a&lt;/sup&gt;</td>
<td>Normal or IFG&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>≥7 and &lt;11.1</td>
<td>262 (24.9)</td>
<td></td>
<td>IGT</td>
<td>IGT</td>
</tr>
<tr>
<td>≥11.1</td>
<td>185 (17.6)</td>
<td></td>
<td>Diabetes</td>
<td>Diabetes</td>
</tr>
<tr>
<td>≥7 and &lt;7.8</td>
<td>&lt;7.8</td>
<td>4 (0.4)</td>
<td>Unclassifiable</td>
<td>Diabetes</td>
</tr>
<tr>
<td>≥7.8 and &lt;11.1</td>
<td>12 (1.1)</td>
<td></td>
<td>IGT</td>
<td>Diabetes</td>
</tr>
<tr>
<td>≥11.1</td>
<td>88 (8.4)</td>
<td></td>
<td>Diabetes</td>
<td>Diabetes</td>
</tr>
<tr>
<td>≥7.8</td>
<td>&lt;7.8</td>
<td>0 (0)</td>
<td>Diabetes</td>
<td>Diabetes</td>
</tr>
<tr>
<td>≥7.8 and &lt;11.1</td>
<td>1 (0.1)</td>
<td></td>
<td>Diabetes</td>
<td>Diabetes</td>
</tr>
<tr>
<td>≥11.1</td>
<td>163 (15.5)</td>
<td></td>
<td>Diabetes</td>
<td>Diabetes</td>
</tr>
</tbody>
</table>

<sup>a</sup> Subjects with FPG ≥ 6.1 and < 7 mmol/l were classified as unclassifiable, those with FPG > 6.1 mmol/l had normal glucose tolerance.

<sup>b</sup> Subjects with FPG ≥ 6.1 and < 7 mmol/l were classified as IFG, those with FPG > 6.1 mmol/l had normal glucose tolerance.
Table 3
Categorization of the 1051 subjects according to values of FPG and a full 75-g OGTT

<table>
<thead>
<tr>
<th>FPG (mmol/l)</th>
<th>Number of subjects (%)</th>
<th>75-g OGTT</th>
<th>1985 WHO criteria</th>
<th>1997 ADA/1998 WHO Consultation criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Normal/</td>
<td>IGT</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>unclassifiable</td>
<td>70</td>
</tr>
<tr>
<td>&lt;6.1 (Normal)</td>
<td>569 (54.1)</td>
<td>307</td>
<td>192</td>
<td>70</td>
</tr>
<tr>
<td>≥6.1 and &lt;7  (IFG)</td>
<td>214 (20.4)</td>
<td>29</td>
<td>70</td>
<td>115</td>
</tr>
<tr>
<td>≥7 (Diabetes)</td>
<td>268 (25.5)</td>
<td>4</td>
<td>12</td>
<td>252</td>
</tr>
<tr>
<td>Total</td>
<td>1051 (100)</td>
<td>340</td>
<td>274 (26.1)</td>
<td>437 (41.6)</td>
</tr>
</tbody>
</table>

of 78.1% when the 2-h PG ≥11.1 mmol/l (200 mg/dl) was used as the reference test, which was higher than our finding. Bias in the tested population may select for a group of subjects in whom the relationship between FPG and 2-h PG is different to that in our subjects. From a large study of 2877 Hong Kong Chinese with various risk factors for glucose intolerance, Ko et al. [13] reported that using the 1997 ADA diagnostic criteria, 394 (13.7%) subjects had diabetes with an FPG ≥7 mmol/l (126 mg/dl). Using a full OGTT according to the 1985 WHO criteria as the reference test, the FPG test had a sensitivity of 57.3%, a specificity of 98.4%, a positive predictive value of 91.1%, and a negative predictive value of 89.2%.

It must be noted that these prevalence estimates of diabetes mellitus and other categories of glucose intolerance in this discussion refer to results of testing on a single occasion. The prevalence of diabetes by a second test as recommended [1–5] will be lower regardless of which criteria are used.

Among our 214 subjects with IFG, 53.7% were diabetic according to a full OGTT based on either the 1985 WHO criteria or the 1997 ADA/1998 WHO Consultation criteria [1,3,5], in contrast with 17.7% of subjects with IFG in a USA population-based study [9]. This is not unexpected because our study population was hospital-based with various risk factors for glucose intolerance. To support this explanation, 21 (30%) of 70 subjects with IFG in a hospital-based study reported by Weiner and Roberts [12] were diabetic based on 2 h plasma glucose ≥11.1 mmol/l (200 mg/dl). Interestingly, the proportions of subjects with IFG classified as diabetic by 2-h PG value were very low, i.e. 2.6, 6.2, and 8.5% among Europeans, Chinese, and South Asians, respectively, according to a population-based study from the UK [10].

Because the sensitivity of the FPG test (≥7 mmol/l or 126 mg/dl) in the diagnosis of diabetics is generally not high, OGTT will probably remain valuable in diagnosing diabetes under certain circumstances, albeit not as a preferred test. However, because of the better acceptance of the FPG test compared to OGTT, it is likely that more screening for diabetes will be done using FPG, and this will result in an increased number of diagnosed cases of diabetes mellitus in a population [1,8]. As many as about 50% of adults with diabetes in the USA are undiagnosed [14,15], depending on the diagnostic criteria used and the study population.

Ko et al. [13] recently reported that combined use of a FPG test and HbA1c or fructosamine for the screening of diabetes in 2877 high-risk Hong Kong Chinese helped to identify potentially diabetic subjects, the diagnosis of which could be further confirmed by a 75-g OGTT. By this approach, about 80% of OGTTs could have been saved, depending on the diagnostic cutoff value of
In conclusion, in a hospital-based group of subjects at increased risk for development of diabetes, FPG ≥ 7 mmol/l (126 mg/dl) as a preferred test for diagnosis of diabetes had a sensitivity of only 57.7%, while the specificity was high, i.e. 97.4%, when a full OGTT based on the 1985 WHO criteria was used as a reference test. Moreover, among subjects with IFG, 53.7% were diabetic and 32.7% had IGT based on a full OGTT. Only 54.0% of subjects with normal FPG had normal glucose tolerance, 12.3% were actually diabetic. Therefore, OGTT remains a valuable test in the diagnosis of diabetes and the classification of various categories of glucose intolerance. The 1997 ADA/1998 WHO Consultation criteria and the 1985 WHO criteria for a full OGTT yield similar overall results.

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References